



*Next Generation Natural Gas Vehicle Activity*

# **U.S. Department of Energy Next Generation Natural Gas Vehicle (NGNGV) Activity**

## **Steering Committee Meeting Washington, DC, July 23-24, 2003**

Dennis Smith, DOE

Richard Parish, Mike Frailey, Margo Melendez, NREL

Douglas Horne, Consultant

Denny Stephens, Battelle



## Next Generation Natural Gas Vehicle Activity

### HQ Corporate

**Assistant Secretary**  
David K. Garman

**Principal Deputy**  
Douglas L. Faulkner

**Board of Directors**

### HQ Program Management

**DAS for Technology Development**  
Richard F. Moorer

**Chief of Staff**  
David Rodgers

#### EERE Program Offices

**Solar**  
Raymond Sutula,  
Acting

**Wind & Hydropower**  
Peter R. Goldman

**Geothermal**  
Peter R. Goldman,  
Acting

**Weatherization & Intergovernmental**  
John P. Millhone

**Biomass**  
Douglas E. Kaempf,  
Acting

**Dist. Energy & Elec. Reliability**  
William Parks

**Industrial Technologies**  
Robert Garland

**Hydrogen, Fuel Cells & Infrastructure**  
Steven Chalk

**FreedomCAR & Vehicle Technologies**  
Edward Wall (acting)

**Building Technologies**  
Michael J. McCabe,  
Acting

**FEMP**  
Elizabeth L. Shearer

### Field Implementation



**6 Regional Offices**



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One objective of the NGVTF is to consolidate previous efforts for more efficient and effective communication and coordination.





## Three Venues for Communication and Coordination

### LEADERSHIP Committee

- Discuss strategic directions and priorities
- Suggest funding approaches

### PROJECTS Coordination Team

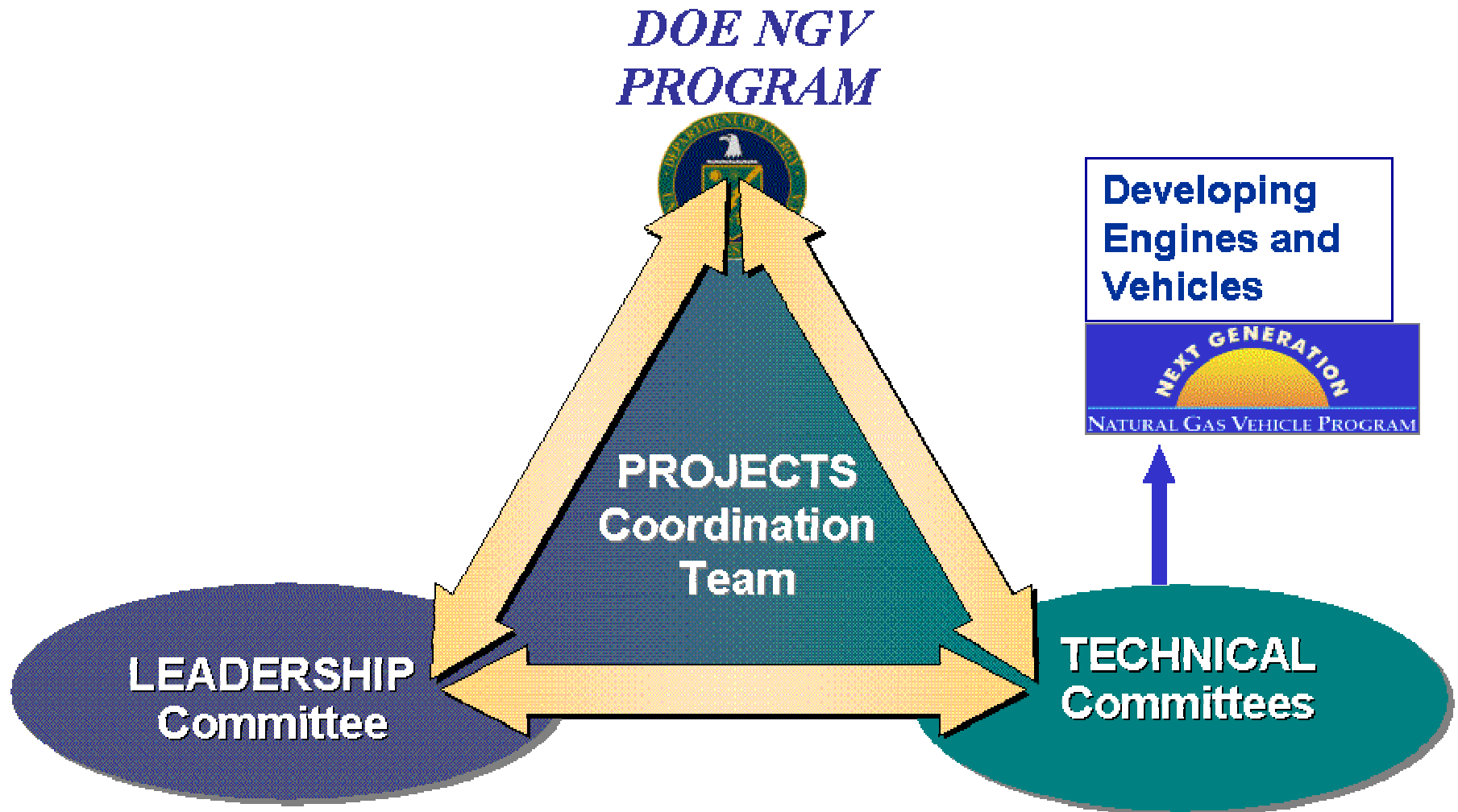
- Confer on funding strategies
- Discuss management of RFPs and contracting
- Lead Technical Committees
- Support communications efforts

### TECHNICAL Committees

- Review technology development and deployment
- Identify problems and obstacles
- Suggest technology enhancement needs



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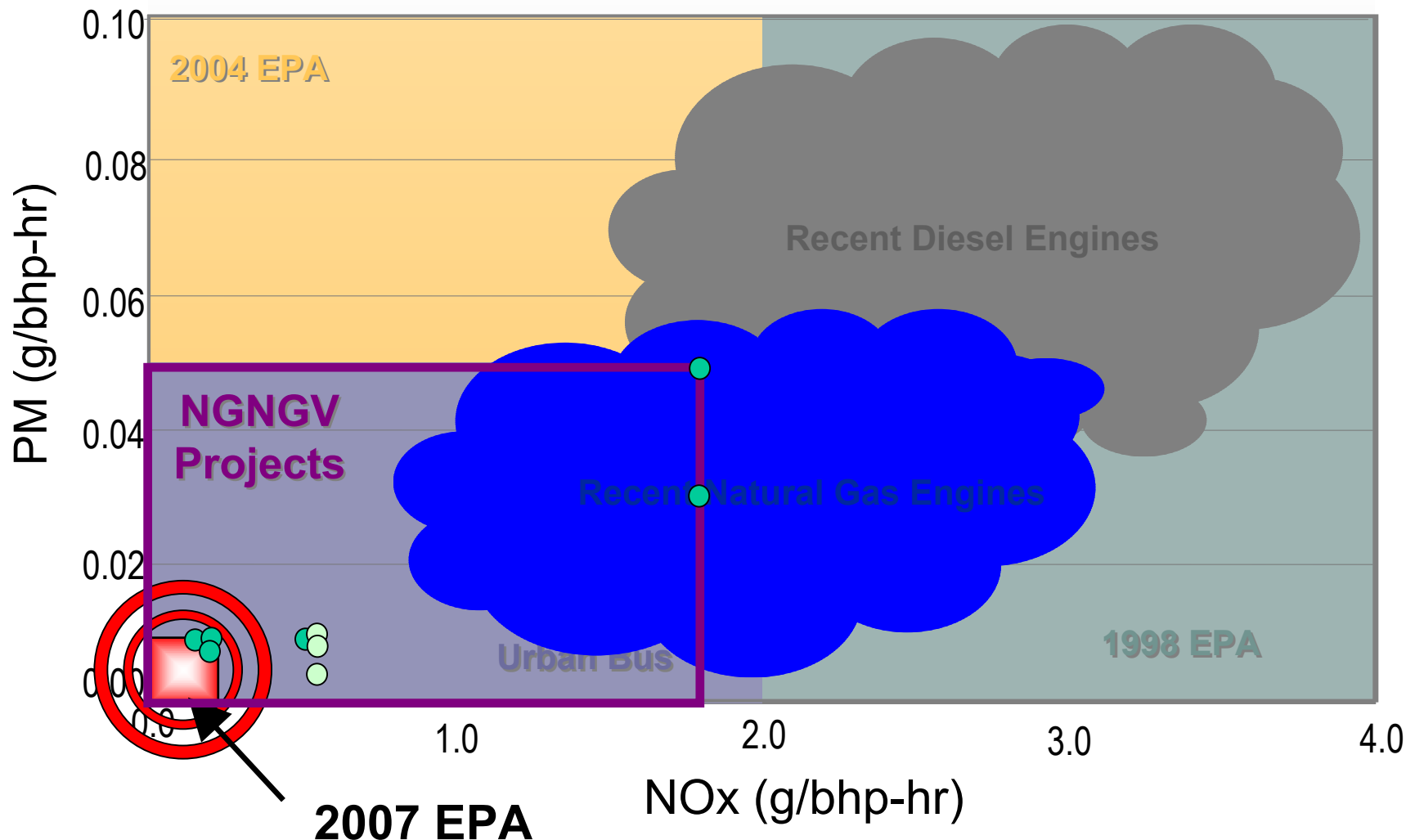




# Targeting EPA 2007 Heavy-Duty Emission Standards



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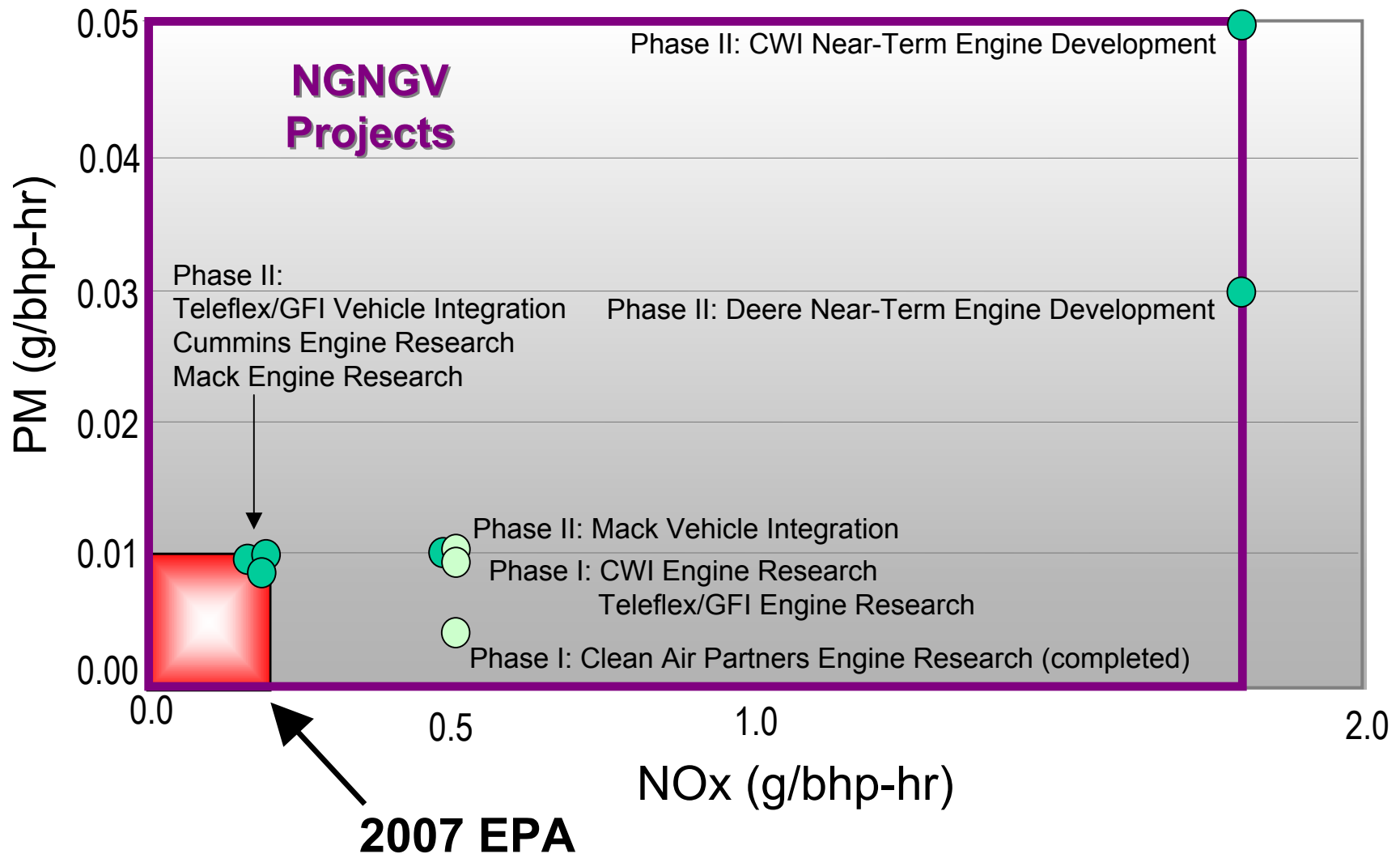




# NGNGV Approaching EPA 2007 Emission Standards



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# Natural Gas Engine Technologies



## Next Generation Natural Gas Vehicle Activity

	Description	Torque/HP	Emissions	Efficiency/ Economy
SING, lean-burn	~10:1 c/r, air throttle, TBI or PFI, turbocharged, lean-burn (up to 26:1), closed-loop	Commercially available Torque 375-1450 ft*lbs Horsepower 150-400 hp SING engines generate less HP and torque relative to DI diesels	Cummins, DDC, Deere, Mack certified to CARB Low NOx (2.0g) & 2004 EPA standard without a/t DDC S50G "Low NOx" project	Commercial products, ample in-use data 20-30% fuel economy penalty ~36% peak efficiency
Dual Fuel	~16:1 c/r, unthrottled, MPI (NG) DI (pilot), ~90% substitution, turbocharged, lean-burn (up to 34:1), closed-loop	Commercially available (Clean Air Partners) Torque 520-1250 ft*lbs Horsepower 190-410 hp	Certified to CARB Low NOx (2.5g) 2004 EPA capable NGNGV Phase I 0.5-g NOx w/EGR & CRT	Commercial products, limited in-use data ~20% fuel economy penalty ~38% peak efficiency
HPDI	~16:1 c/r, unthrottled, HPDI (pilot & NG), ~92% substitution, turbocharged, lean-burn (equivalent w/diesel ~100:1), closed-loop	Development engines in field (CWI) Torque 1450 ft*lbs Horsepower 400 hp "Low NOx" Development 1650 ft*lbs/450 hp	Certified to CARB Low NOx (2.5g) 2004 EPA capable CWI ISX-G "Low NOx" project	Preliminary in-use data 10-15% fuel economy penalty 42% peak efficiency "Low NOx" 41% peak efficiency





# Natural Gas Engine Technologies (continued)



## Next Generation Natural Gas Vehicle Activity

	Description	Torque/HP	Emissions	Efficiency/ Economy
Micro-Pilot (<1% pilot fuel)	~16:1 c/r, unthrottled, MPI (NG) DI (pilot), 99% or greater substitution, turbocharged, lean-burn, closed-loop	Prototype generator sets (Clean Air Partners) No automotive applications Torque and HP ratings equivalent to Dual Fuel, HPDI and diesel	Potential to meet 2010 EPA emission standards w/EGR & CRT	Same efficiency as Dual Fuel ~38% peak efficiency
SING, stoich w/EGR & TWC	Up to 12:1 c/r, air throttle, TBI or PFI (NG), turbocharged, stoichiometric a/f, EGR, TWC, closed-loop	Commercial stationary applications Phase II NGNGV Engine R&D projects Small rating increase relative to lean burn-SING	Potential to meet 2010 EPA emission standards	~40% peak efficiency
HCCI	Wide range of up to 20:1 c/r, unthrottled, variable valve operation/timing	Experimental phases only Phase II projects could assist with future development of this technology	Unknown	Linear relationship between increase in c/r and reduction of thermal efficiency

a/f—air fuel ratio; a/t—aftertreatment; CARB—California Air Resources Board; c/r—compression ratio; CRT—continuously regenerating technology; CWI—Cummins Westport Inc.; DDC—Detroit Diesel Corp.; DI—direct injection; EGR—exhaust gas recirculation; HCCI—homogeneous charge compression ignition; HPDI—high-pressure direct injection; MPI—multi-point injection; NG—natural gas; PFI—port fuel injection; SING—spark-ignited natural gas; stoich—stoichiometric; TBI—throttle body injection; TWC—three-way catalyst.



# NGNGV Phase I Project Overview



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NGNGV Phase I	FY01	FY02	FY03	FY04	FY05	FY06	FY07
<b>Phase I Engine Research (0.5 g/bhp-h NOx, 0.01 g/bhp-h PM)</b>							
<b>Clean Air Partners, Class 6-8 (NREL)</b> Cat 12.0L, Dual-Fuel, EGR, 410 hp, 1250 ft-lb							<b>COMPLETED</b>
<b>Teleflex GFI, Class 3 (NREL)</b> GM 6.0L, SING-stoich, 286 hp, 317 ft-lb							<b>COMPLETED</b>
<b>Cummins Westport, Class 3-6 (SCAQMD)</b> CWI ISB 5.9L, SING-lean burn w/AT, 230 hp, 500 ft-lb							
<b>Phase I Engine Component Research</b>							
<b>TIAX (NREL)</b> Catalytic glow plugs and shields							<b>COMPLETED</b>
<b>Phase I Market Assessment</b>							
<b>Cummins Westport (SCAQMD)</b> Strategy for Class 3-6 CNG & Class 7-8 LNG trucks							



# NGNGV Phase II Project Overview



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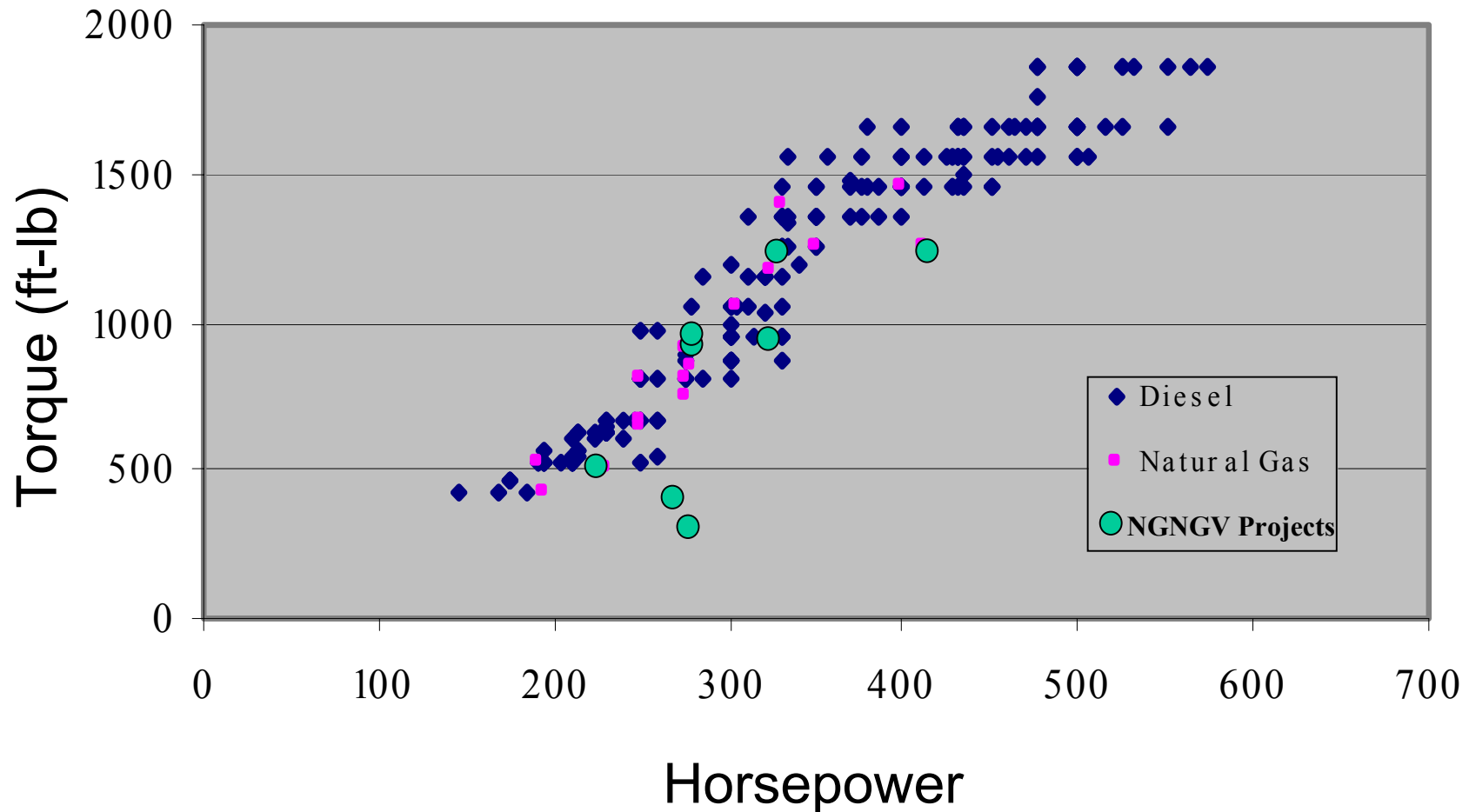
NGNGV Phase II	FY01	FY02	FY03	FY04	FY05	FY06	FY07
<b>Phase II Near-Term Engine Development (1.8 g/bhp-h NOx, 0.05 g/bhp-h PM)</b>							
<b>Cummins Westport, Class 6-8 (NREL)</b> CWI ISL 8.9L, SING-lean burn, 320 hp, 950 ft-lb							
<b>Deere, Class 6-7 (NREL)</b> Deere 8.1L, SING-lean burn, oxy cat, 280 hp, 900 ft-lb							
<b>Phase II Engine Research (0.2 g/bhp-h NOx, 0.01 g/bhp-h PM)</b>							
<b>Mack, Class 6-8 (NREL)</b> Mack 11.0L, SING-stoich, 325 hp, 1250 ft-lb							
<b>Cummins, Class 3-6 (SCAQMD)</b> Cummins 8.3L SING-stoich w/EGR, TWC, 280 hp, 950 ft-lb							
<b>Phase II Vehicle Integration (0.5 g/bhp-h NOx, 0.01 g/bhp-h PM)</b>							
<b>Mack, Class 6-8 LNG (NREL/SCAQMD)</b> Mack E7G 12.0L, SING-stoich, EGR, TWC, 325 hp, 1250 ft-lb							
<b>Teleflex/GFI CNG, Class 3-6 (NREL)</b> GM 8.1L, SING-stoich, 270 hp, 400 ft-lb							



# Medium- and Heavy-Duty Engine Availability Examples



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# NGNGV Steering Committee Meeting Agenda – Wed 7/23



## *Next Generation Natural Gas Vehicle Activity*

- 8:00 Welcome
- 8:15 Project Overview/Preview
- 9:15 Project Reviews
- 9:15 Clean Air Partners (1/2 hour) (Mike Frailey, NREL)**  
Phase I Engine Research: Conceptual 0.5 g/bhp-h NOx Engine
- 10:00 Deere (1 hour) (Johannes Inzenhofer, Deere)**  
Phase II Near-term Engine Development: 1.8g/bhp-h NOx+NMHC 8.1L Engine
- 11:00 Lunch Break
- 12:30 Cummins/Cummins-Westport (4-1/2 hours) (Mostafa Kamel, Edward Lyford-Pike, Cummins)**  
Phase I Engine Research: Hot Surface Ignition-Catalyzed Glow Plug Development  
Phase I Engine Research: ULTRA Low NOx, Lean-Burn SI  
Phase II Near-term Engine Development: 1.8g/bhp-h NOx Engine  
Phase II Engine Development: 0.2g/bhp-h NOx Engine  
Phase I Market Assessment: NG Engine and Vehicle Market Analysis



# NGNGV Steering Committee Meeting Agenda – Thurs 7/24



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- 8:00      Teleflex/GFI (1 hour) (Steve Petchkoff, Teleflex/GFI)**  
Phase I Engine Research: Medium Duty Low NOx CNG Engine  
Phase II Vehicle Development: Medium Duty Low NOx CNG Vehicle
- 9:15      Mack (2 hours) (Ken Murphy, Chun Tai, Mack)**  
Phase II Engine Development: Heavy Duty 0.2g/bhp-h NOx Engine  
Phase II Vehicle Development: Heavy Duty 0.5g/bhp-h NOx Refuse Hauler
- 11:15      Lunch Break**
- 1:00      Steering Committee Discussion of Current Projects**
- 2:00      Identification of Future Projects/Activities**
- 3:00      Discussion of Possible NGV-TF Presentations/Updates**



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### **Outcomes**

- Excellent progress with limited funding...need more money (heavy duty, LNG applications)
- Fuel efficiency needs to be maintained and improved
- Appears to be greater support from OEM leadership
- 0.2 g/bhp-hr NO<sub>x</sub> is attainable with NG...need to get this word out – a clear communications strategy
- Address all emissions issues (particularly formaldehyde)
- Stoichiometric w/EGR is a technology which enables the use of 3-way catalysts
- Cost for diesels to achieve 2007 - 2010 standards will be high
- Need to get vehicle OEMs involved, working platform integration issues
- NG engine technologies should be compatible with HCNG



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### **Outcomes (cont'd)**

- Product sales and business case are important (need market pull)
- Vehicle development/integration could be sponsored by Clean Cities

### **Next steps**

- Fill gaps of engine availability (high hp/high torque)
- Aggressively pursue 0.2 g/bhp-hr NO<sub>x</sub>
- Commercial CNG engine into hybrid electric integration project
- Actively communicate successes to date
- NGNGV status teleconference on a bi-monthly basis
- Two-page fact sheet on status of NGNGV activity for NGVTF meeting
- Internal DOE program review (with FCVT and HFCIT programs)